An Energy Efficiency Workshop & Exposition

Palm Springs, California

Distributed Generation and Reliability

US Department of Energy

Federal Energy Management Program

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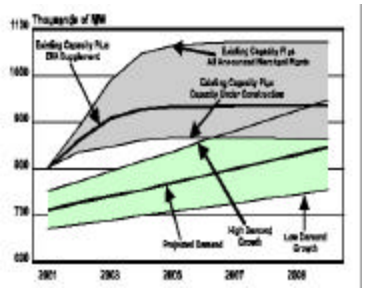
NERC System Reliability

- System Adequacy
  - Available generation > demand plus losses
  - Transmission capability> overload condition
  - Acceptable voltage
- System Security
  - Static security: adequacy if equipment removed
  - Transient security: system returns to synchronous state after sudden loss of equipment.

Source: H. Merrill, Electric Power Engineering
www. energy2002.ee.doe.gov

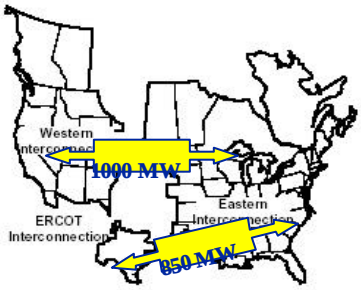
Merchant Plants should help GENERATE enough power…



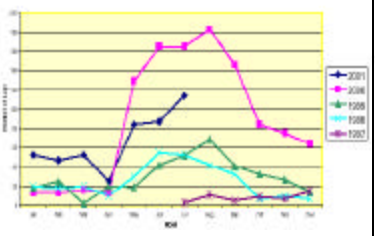
- **Old:** planned by utilities and regulators
  - percent reserve margin
  - loss-of-load probability
- **New:** planned by developers
  - greatest financial return
  - low capacity margins
  - access to fuel supplies
  - access to transmission
  - ease of permitting.
  - Business cycle: feast or famine

Source: Reliability Assessment 2001–2010 North American Electric Reliability Council October 16, 2001

…but there are limits on the ability to TRANSMIT power…

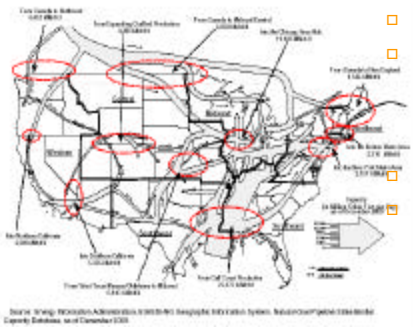


Transmission between interconnections limited by capacity of High Voltage DC connections



Number of Transmission Load Relief (TLR) events, where transactions are limited by available transmission capacity

Got Gas?



- Most new plants are natural gas fired
- Spot market
- Ability to get gas to plants.
  - Aging pipelines
  - Lack of redundancy
  - Shifting sources and users
- Siting of new pipelines
- Non-renewable resource
  - New extraction technology
  - New places to drill
  - 1,331 TCF total US resource base (42 years supply), 164 TCF proved reserves

System Disturbances in 2000

- 58 disturbances
  - 28 severe weather.
  - 12 personnel actions
  - 10 equipment failure
- 3,236,000 customers interrupted

Source: NERC

Deregulation

- Pre-deregulation reliability
  - voluntary efforts and "peer pressure" to ensure compliance with NERC standards.
  - users and operators of the system **cooperated** with each other
- Post-deregulation
  - users and operators **compete** rather than cooperate
  - effective recourse and mandatory enforcement of a fair and impartial single bulk electric system reliability standard must be established
  - NERC has proposed self-regulating reliability organization (SRRO) to develop and enforce rules with FERC

Average Utility System Availability 99.97% ("3 nines")

Typical reliability index values for U.S. utilities.

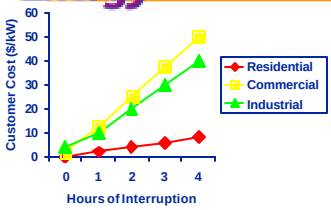
	SAIFI[1] (events per year)	**SAIDI**[2] (minutes per year)
Average of top 25%	0.90	54
Average of 50% - 75%	1.10	90
Average	1.26	117
Average of 25% - 50%	1.45	138
Average of bottom 25%	3.90	423

[1] SAIFI (System Average Interruption Frequency Index) — the average number of interruptions experienced by customers per year.

[2] SAIDI (System Average Interruption Duration Index) — the average number of interruption minutes experienced by customers per year.

Source 1995 IEEE survey

Question: "Is that good enough?" Answer: "It depends."



For most of us it's *too good*, at less than $4/kW outage (IEEE, 1999).

For data centers its *not good enough*, at $10,000/kW

Cybercon Data Center, St. Louis

Outage at New Mexico High School State Basketball Championship game

When your son takes *the* shot, it's *priceless*.

At a crossroads: communal response or every-man-for-himself?

- Reliability is costly
- **Old**: Reliability used to be a "public good" with broad cost recovery. Regulators set high standards, which benefited the few who needed it.
- **New**: Different levels of reliability will be provided to customers with different reliability needs, and the will to pay more for it.
  - Differentiated service
    - Multiple feeders
    - Preferential service
    - On-site solutions

Enter the Customer-based solution.

- Electric Power Technologies
  - Regulating transformers
  - Surge suppression
  - Uninterruptible Power Supply (UPS)
  - Distributed Generation
  - Multiple Utility Feeders
- Demand Side Measures
  - Data / process management
  - Daylighting
  - Passive Solar Heating
  - Cooling Load Avoidance
  - Natural Ventilation

Uninterruptible Power Supply

- UPS for momentary interruptions and voltage sags
  - Lead Acid Batteries ($13 / kW sec)
  - Ultra Capacitor ($70 / kW sec)
  - Superconducting ($200 / kW sec)
  - Rotary (flywheel)

Source: Brown and Marshall, ABB Consulting

Distributed Generation

- For longer term outages, need no T&D
  - Internal Combustion Engines (91.2-95.8%)
  - Gas Turbines (90.0 - 93.3%)
  - Fuel Cells (63.5 -99%)
  - Photovoltaics (86.4 -96.2%)
  - Wind Power

Sources: GRI, DODFuelCell, SMUD,

Mind Your P's and Q's…

- P = probability resource is available
- Q = probability resource is unavailable
- $P_{utility} = 0.9997$, $Q_{utility} = 0.0003$
- Consider 800 kW reciprocating engine generator $P_{gen} = 0.9120$, $Q_{gen} = 0.088$
- Availability of EITHER utility OR generator $=P_{utility}P_{gen} + P_{utility}Q_{gen} + P_{gen}Q_{utility} =0.99997$
- An improvement from "3 nines" to "4 nines" due to the generator

How many generators do you need to get the "nines" you need?

P+Q=1

Total number of generators = n

Reserve is excess of those to meet the load = r

$(P+Q)^n = 1$

$P^n + nP^{n-1}Q + n(n-1)P^{n-2}Q^2/2! + \ldots + = 1$

Add up the first r+1 terms to find the probability that system will operate at the desired capacity, then iterate again with the new n

Optimization Example

- Say we need 12 MW with 98% reliability
  - 34 * 400 kW generators = 13,600 kW (n=34 r=4, CF=.635)
  - 23 * 600 kW generators = 13,800 kW (n=23, r=3, CF=.626)
  - 13*1,200 kW generators = 15,600 kW (n=13, r=3, CF=.554)
- This argues for a modular plant with many small generators, BUT, cost per kW goes down with generator size.
- In this example, the 600 kW size results in the lowest cost of power.

Example: First National Bank of Omaha

- 320 kW Credit Card Processing
- Outage losses $6,000,000 / hour
- Feeders from 2 different substations
- Two 1250 kW Diesel Generators
- Four 200 kW Fuel Cells
- 4 Rotary UPSs
- Calculated availability 99.999995% (“7 nines”)

Source: Thomas J. Ditoro, HDR Architecture, Inc.

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Thank You

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